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TIMES OF DEFORMATION IN THE CANADIAN APPALACHIANS

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This short paper summarizes the constraints on the times of deformation upon which the Structural Map of the Appalachian Orogen in Canada (1) was based. Space does not permit a detailed description of the structural styles, which may be found in (2) and references therein.

The times of deformation fall into several periods (Table 1): Mid Proterozoic or earlier (e.g. Grenvillian, Micmacian), Late Proterozoic (Cadomian = Avalonian), isolated Early Ordovician (Penobscotian), Mid-late Ordovician (Taconian), Devonian and possibly latest Silurian (Acadian) and Permo-Carboniferous (Hercynian).

MID PROTEROZOIC OR EARLIER

Rocks of the Grenville Province form the cratonic margin of ancient North America and generally crop out along the western side of the Appalachian Orogen (3). Elsewhere in the orogen, Mid Proterozoic rocks crop out in isolated basement blocks such as in the >1600 Ma gneisses in the Chain Lakes block (4), in the >1000 Ma Gneisses in Cape Breton Island (5), and in the >1180 Ma gneisses in the Meguma Zone (6). Since these rocks formed prior

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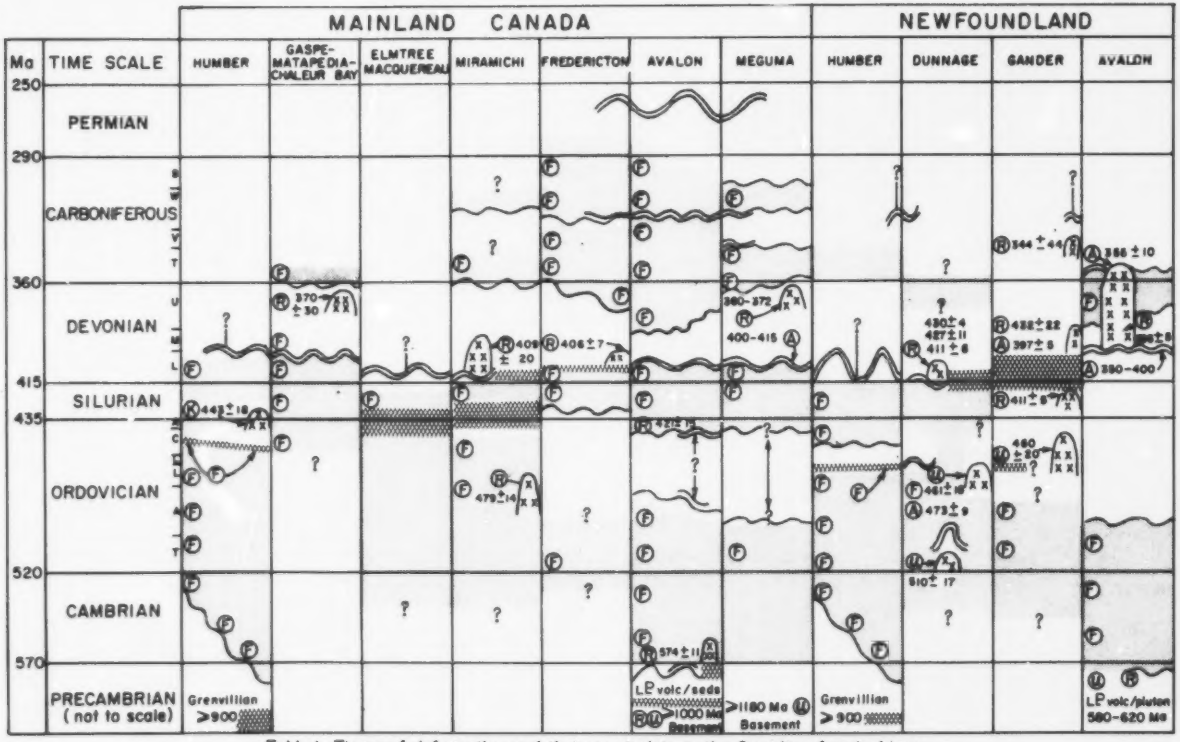

Table I. Times of deformation and their constraints in the Canadian Appalachians.

to the Appalachian cycle, they are beyond the scope of this paper.

LATE PROTEROZOIC

The Late Proterozoic Cadomian (Avalonian) deformation is confined to the Avalon Zone (Table 1). The intensity of deformation varies from weak to absent in Newfoundland and the central to eastern Caledonian Highlands of New Brunswick, where it is represented by disconformities, nonconformities, and unconformities, to penetrative polyphase deformation in Nova Scotia and the western Caledonian Highlands (7). Lower limits on the time of deformation are only available in Newfoundland where volcanics of the Marystown and Love Cove Groups have yielded U-Pb zircon dates of 608 ± 25 Ma and 590 ± 30 Ma respectively (8), and an U-Pb age on the Holyrood Granite of 620 ± 2 Ma (9). Dating of the volcanic rocks in Nova Scotia and southern New Brunswick by Rb-Sr has yielded anomalously young ages. Upper limits on the time of deformation are provided by Early Cambrian fossiliferous strata lying unconformably to disconformably upon older rocks, and post-tectonic plutons the oldest of which is the Shunacadie pluton at 574 ± 11 Ma (Rb-Sr whole rock isochron 10) and the 593 ± 28 Ma K-Ar age on hornblende from the Coxheath Hills pluton (11) both in Cape Breton Island, Nova Scotia. If the base of the Cambrian is at 570 Ma then these data bracket the time of deformation between 570 and 620 Ma.

EARLY ORDOVICIAN

Deformation during this time interval is restricted to Twillingate in Newfoundland (12). Here, the Twillingate granite with an U-Pb intrusive age of 510 ± 17 Ma is affected by a weak to penetrative foliation, which in turn is cut by post-tectonic mafic dykes. The oldest of these dykes yielded a 473 ± 9 Ma ^{40}Ar-^{39}Ar age on hornblende.

MID-LATE ORDOVICIAN

The effects of the Taconian deformation are recorded mainly from the Humber Zone along the northwestern flank of the orogen (Table 1), although local effects also occur in the Dunnage, Avalon and Meguma Zones (1). In the Humber Zone, the structures are predominantly nappes and thrusts which become refolded towards the southeast. The earliest record of regional Taconian deformation in the Humber Zone is given by the age of genetically related development of olistostrome. In Quebec, this olistostrome is Caradocian becoming younger across the zone from

the internal nappes to the external nappes (13). It is also diachronous along the Humber Zone because the same olistostrome is Llanvirn in Newfoundland. An upper limit on the time of deformation is given by the Caradocian age of the Long Point Group that unconformably overlies the transported rocks (14, 15). In Quebec it is provided by cooling ages on hornblende produced during associated regional metamorphism, the oldest of which is a K-Ar age of 443 ± 18 Ma on amphibolites from Mont Albert (13).

In the Dunnage Zone of Newfoundland, the rocks are not generally polydeformed and they are everywhere less intensely deformed than those of the orthotectonic part of the Humber Zone. In central Notre Dame Bay, Ordovician and Silurian sequences are conformable and were first penetratively deformed by the Acadian (16). The time of deformation on the Baie Verte Peninsula is bracketed by the Arenigian Snooks Arm Group, the U-Pb zircon age of 461 ± 15 Ma on the pre-Taconian deformed Burlington granodiorite (8), and the oldest, post-tectonic, unconformably overlying, unfossiliferous Cape St. John and MicMac Lake Groups of presumed Silurian age. Tight constraints on the times of deformation in the Gander Zone in Newfoundland are absent and all could be attributed to the Acadian orogeny.

Taconian polyphase deformation appears to be youngest in the central part of the orogen in Quebec and northern New Brunswick: Macquereau, Elmtree and Miramichi blocks (17) (Table 1). The time of deformation is best defined in the Miramichi block where the stratigraphic record is most complete. Here the time of deformation is bracketed by the mid-Caradocian age of the youngest deformed rocks (17) and the Ludlovian age of the unconformably overlying strata. In the Elmtree block, the oldest post-Taconian rocks are Llandovery C3-C4 (18). It is interesting to note that the central part of the Matapedia Basin was the site of continuous deposition from Caradocian through the Silurian, i.e. synchronous with Taconian deformation both to the north and south (17).

In the Avalon and Meguma Zones of Nova Scotia and southern New Brunswick, an unconformity is present between Cambrian-Arenigian and earliest Silurian strata (Table 1) (19). Structures associated with this regional uplift are only rarely recorded, e.g. adjacent to the Hollow Fault in the northern Antigonish Highlands Llandoverian rocks rest unconformably upon recumbently folded Cambrian-early Ordovician rocks (20).

DEVONIAN (AND POSSIBLY SILURIAN)

The effects of the Acadian Orogeny are widespread through the Canadian Appalachians varying from upright folds over rigid basement blocks to polyphase deformation in some troughs. Examination of the Structural Map of the Appalachian Orogen in Canada (1) and Table 1 suggests that the time of Acadian deformation ranges from Silurian to Devonian. However, while this may be the case, it may also be an artifact of the dating method and the placing of the Siluro-Devonian boundary at 415 Ma. Thus, where the stratigraphic record is used, the youngest pre-Acadian, penetratively deformed rocks are Emsian (Early Devonian) in age (21, 22) and the oldest post-tectonic strata range from Middle Devonian to Early Carboniferous. Although locally, the Mid-Late Devonian rocks are also tilted and folded they are generally not penetratively deformed. However, where stratigraphic relationships are limited or absent as in the Gander Zone and parts of the Dunnage Zone in Newfoundland, the oldest post-tectonic plutons are the Hodges Hill pluton at 411 ± 6 Ma and the Middle Brook pluton at 432 ± 22 Ma (both Rb-Sr whole rock isochrons) (23). At face value these data imply a Silurian or Siluro-Devonian time of deformation. However, in the Fredericton trough, deformed Gedinnian Eastport Formation is intruded by the post-tectonic St. George granite dated at 406 ± 7 Ma by Rb-Sr whole rock isochron (24). Direct measurements of the age of the Acadian deformation by ^{40}Ar-^{39}Ar total gas ages on slates in the Meguma Group range from 400 to 415 Ma (25) and phyllites in the Love Cove Group from the Newfoundland Avalon Zone range from 350-400 Ma (8). Considering the data as a whole it appears that either the 415 Ma age on the Siluro-Devonian boundary is too young, or that the isotopic data are inaccurate. If the Siluro-Devonian boundary is older, then all the deformation could be accommodated in the Devonian.

PERMO-CARBONIFEROUS

Permo-Carboniferous Hercynian deformation was most intense around the margins of the Magdalen Basin (19) dying out onto the surrounding platforms and towards the centre of the basin. Structures are generally upright folds with and without attendant cleavage; however, refolded recumbent folds and thrusts are developed in certain narrow zones and in the Visean rocks where gravity sliding on evaporites occurs. In and around the Magdalen Basin, where the stratigraphic record is most complete, there appear to be three main times of deformation during Late Tournaisian, Westphalian B-C and Late Permian times. However, there are also many other local unconformities as would be expected in a predominantly terrestrial sequence. The Westphalian time of deformation is documented by the sub-Pictou

Group unconformity which cuts across rocks ranging in age from early Paleozoic to Westphalian B. The Pictou Group spans the Westphalian C to Early Permian, and was deformed during the break in the stratigraphic record between Early Permian and Late Triassic times.

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